Estimating Demand for Value Pricing Projects

State of the Practice

prepared for

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Introduction

As a travel demand management strategy, value pricing is gaining popularity in regions with traffic congestion problems, offering congestion relief through the implementation of user fees that would vary by time of day and level of roadway congestion. Examples of such strategies include introduction of variable tolls on toll roads, parking pricing, mileage-based pricing, and conversion of higher occupancy vehicle lanes to higher occupancy toll lanes where the excess capacity of HOV lanes is offered to single-occupant-vehicles who are willing to pay a toll in exchange for improved travel times. Diversion of drivers from the mixed-flow lanes to managed lanes, in turn, brings about some degree of congestion relief for the adjacent general-purpose lanes and can result in net benefits from reduced travel time and vehicle miles of travel by offering users incentives to economize on daily travel. Implementation of value pricing policies will also result in generation of additional revenues, which can pay for the operation and maintenance of the facility over time.

Modeling the effects of managed lanes within the context of a travel demand forecasting model is just as recent as the implementation of the policy itself. Questions are posed concerning the optimum toll, generated managed lane demand, as well as the potential latent demand in the target corridor. Value pricing projects are evaluated with respect to relief of congestion, equity, economic benefits, and air quality. The intent of this report is to summarize and compare the existing modeling procedures addressing value pricing strategies involving tolls.

There are but a few metropolitan planning organizations (MPO) that have developed procedures for the estimation of demand for managed lanes. Procedures employed in modeling and estimating demand for such projects range from sketch planning, to post-processing methodologies, to the implementation of procedures adapted for use with state-of-the-practice four-step travel models and state-of-the-art activity-based models. This paper presents a summary of some of the existing methodologies in the country. It presents work done in Portland, Phoenix, Atlanta, Pittsburgh, Washington D.C., San Diego, Sacramento, Minneapolis-St. Paul, and Northern Virginia. A number of other MPOs were also contacted that had no procedures in place to address estimated demand for managed lanes (e.g., Los Angeles, San Francisco, Detroit, and Seattle-- although Seattle is currently in its initial phase of a major value pricing project). The paper concludes with a summary comparison of the documented procedures and short- and long-term recommendations regarding value pricing modeling options for the North Central Texas Council of Governments (NCTCOG).

Papers and model documentation used in the preparation of this report are cited under 'References' and may be tapped into for further exploration. More often than not detailed documentation did not exist or could not be obtained for the existing procedures. A number of agencies with managed lane modeling procedures but no formal documentation generously made available information regarding their approaches either by means of telephone conversations, e-mail correspondence, or personal interviews. The brevity of descriptions for some of the procedures is reflective of the absence of detailed documentation and other reference materials.

Portland, Oregon

Portland's methodology used in modeling and evaluating value pricing projects is by far the most sophisticated of those documented in this report. It may be classified as the state-of-the-art among all existing methodologies. Portland Metro developed the evaluation procedure as part of the Traffic Relief Options Study (TROS) (1). The study was initiated in mid-1996 with a pre-project grant from FHWA. The evaluation methodology was driven by Metro's tour-based activity model estimating the effects of various pricing options on mode, route, time of day, and destination choices, by income class and trip type.

Portland's activity-based travel models were developed as part of the Travel Model Improvement Program (TMIP), and were estimated using data from a two-day activity-based household travel survey conducted in the Portland area in 1994 and 1995. The revealed-preference estimation database was augmented by samples obtained from three stated-preference surveys: commute/non-commute pricing survey, auto acquisition survey, and urban design/residential location survey. The model is comprised of a series of disaggregate and nested logit discrete choice models presented in a hierarchy of model components (2). Currently, there are very few activity-based travel models in operation in the U.S. The use of the Portland model as part of the evaluation methodology in TROS was the first such application in an actual policy setting.

The model system has several components, at the highest level of which stands the full day activity pattern model, predicting a person's daily activity patterns and the trip chains associated with that. Primary and secondary tours made up of a chain of trips are the unit of travel in such models. A time of day model determines the timing of activities. A person's activity pattern is thus predicted in terms of frequency, timing, purpose, and complexity of the tours. A joint destination and mode choice model is applied at the primary home-based tour and secondary work-based tour levels. Within the model, each decision is highly conditional upon higher-level decisions, while those higher-level decisions have full information regarding lower level choices.

The model was applied for the Traffic Relief Options Study using the regional 1,260 transportation analysis zones. One of the input requirements for the model is a set of auto travel times stratified by time of day, income (low, medium, and high), and auto occupancy (SOV and HOV). Overall, a total of 24 auto travel time skim tables are used by the model. Generation of these travel times requires several iterations of model runs.

A time-equivalent toll is added to the skimmed auto travel time for scenarios involving a toll. Link-based travel times representing tolls are generated using a generalized cost multi-class equilibrium assignment and a special toll cost volume delay function, implemented using the EMME2 software platform. The assignment procedure uses two classes of demand: passenger cars and trucks (expressed in passenger car equivalents). A subsequent all-or-nothing assignment using the tolled volumes from the previous step, but without the toll in the delay equation produces link times without tolls. The difference between the two travel times obtained under the first and second assignments are link tolls in minutes.

The above-mentioned toll times and eight vehicle classes (SOV low, medium, and high income; HOV low, medium, and high income; external vehicles; trucks) are used in a seventy-five iteration assignment procedure. A toll weight, derived from survey data and the base year demand, is assigned to each vehicle class. The weights suggest that all else being equal, high-income travelers are twice as likely to use a tolled facility than those in lower income brackets.

The procedure is designed to post a toll on each individual tolled link based on the supply and demand for each tolled link and the competing non-tolled links. The procedure is applied for each modeled time of day. Trip tables are generated by mode (drive alone, drive with passenger, auto passenger, bus/walk access, bus/auto access, LRT/walk access, LRT/auto access, walk, and bicycle), time of day, income, and trip purpose. In the interest of time, the model was calibrated using a pivot point approach and trip tables from the existing four-step model for work/non work highway and transit trips.

Phoenix, Arizona

The Maricopa Association of Governments (MAG) uses an iterative procedure to estimate demand and tolls for its network's managed lanes. Tolls are coded as per-mile costs on candidate freeway links. After an initial model run, congestion on candidate managed lanes is calculated with the goal of maintaining a level of service D/E. Given the level of congestion, tolls are determined and adjusted in an iterative manner in order to determine the optimum value at which enough SOV traffic is diverted from freeway main lanes to take advantage of the managed lane's excess capacity, while maintaining the desired level of service and preventing the build-up of traffic congestion to compromise faster travel times.

MAG's recently upgraded four-step travel demand forecasting model accommodates the task of modeling tolled alternatives by means of a toll/non-toll nest in its Mode Choice model (3). The nest is structured under the Drive Alone branch of the nested logit model, reflecting MAG's policy of requiring a minimum of only two occupants for the use of HOV lanes. Therefore, managed lanes are only marketable to SOV users. Tolls are included in the utility of the SOV/Toll alternative. Also included is a travel time savings term equivalent to the difference between tolled and non-tolled travel times. This is similar to the travel time savings term present in the utility of shared ride alternatives expressed as the difference between HOV and non-HOV times. These terms are also referred to as the HOV or toll lanes 'reliability' factors, adding to the attractiveness of that alternative, all else being equal. MAG's mode choice program outputs toll-eligible and non-toll eligible trip tables, which are assigned using EMME2's multi-class assignment procedure; only toll-eligible trips get to use the faster toll lanes.

MAG's trip distribution model is a gravity model using the Gamma function and a generalized cost impedance measure with the following variables: highway time, highway distance, door-to-door transit time, and transit fare. Thus, the model is sensitive to both highway and transit service for the distribution of zonal trip ends.

MAG is currently in the process of calibrating a revised trip distribution model replacing the generalized cost impedance with the LOGSUM term out of the mode choice model, enabling the model to be responsive to toll costs as well.

Atlanta, Georgia

The Atlanta Regional Commission (ARC) uses a post processing assignment technique to estimate demand resulting from the implementation of managed lanes on HOV facilities. The toll charged to SOV and truck trips for the use of the HOV lane is set at a level to utilize the excess capacity of the HOV facility but would increase as the level of congestion on HOV also increases in order to maintain the desired level of service of the managed lane. The highway toll cost is a variable in the utilities of the four auto modes (SOV, HOV2, HOV3, HOV4+) within ARC's mode choice model. The shortest highway time path is selected, so each trip interchange in the mode choice model either includes a toll or not.

The actual toll cost is interpolated between a lower and an upper range based on the V/C ratio of the managed lane. Tolls are converted to travel time equivalents and are added onto the non-toll travel time of the link. The managed lane tolls change from one iteration to the next as a means of equilibrating supply and demand. Link-based tolls are set low enough to encourage usage and high enough to discourage congestion. The procedure is implemented using a special assignment script within the TP+ software platform. HOV links are initially flagged on the highway network. After the completion of a full model run, candidate HOT lanes on the HOV network are flagged as such, followed by the assignment of time-of-day trip tables generated from the original model run.

Truck and SOV trips, for any given origin-destination pair, are assigned to either a tolled-path or a non-tolled path during each assignment iteration. Trips will choose the tolled path, if it offers a shorter travel time, particularly since a time penalty is used as a proxy for managed lane tolls. The algorithm is designed to set the tolls at a level that encourages usage, but prevents congestion in managed lanes. The choice between the paths may change between iterations. Once the assignment procedure is complete, a portion of each *i-j* pair's trips is included as non-toll trips and a portion as toll trips. The resulting volume is a weighted average of all iterations' volumes. The decision to use this "pseudo probabilistic" approach was based on processing time. The probabilistic procedure in the main model requires building tolled and non-tolled paths twice for each iteration, once for the toll model and then again for the assignment.

The managed lane per-mile tolls increase sharply beyond a V/C Ratio of 0.8, so that the facility can still offer travel-time savings to its travelers. The methodology is a tool that helps determine the most efficient toll to collect (lower tolls if under-used, and higher tolls if over-used). If the competing facilities are not congested enough, then no SOV and trucks volumes are assigned on the HOT lanes. The resulting loaded network together with a series of corridor reports summarizing performance statistics such as managed lanes V/C ratio, truck and SOV vehicle miles of travel on the managed lanes, and calculated average per-mile toll for trucks and SOVs allow for the evaluation of tolled alternatives in the study corridor, as well as the estimation of weekday revenues for each corridor.

The managed lane methodology is applied as a post-processor, primarily, due to the processing time involved. With five feed back loop iterations and four time of-day assignments, a full model run lasts for 9-13 hours. Integrating the managed lane assignment, which normally lasts twice as long as a normal assignment, would considerably add to the run time duration.

Since no managed lanes exist in the Atlanta area, the value pricing methodology could not be truly validated except for a series of reasonability checks. The default per-mile costs are similar to those that are in place on existing toll facilities around the country. The procedure has produced tolls in the 12 to 15 cents per mile in the I-75 and I-85 corridors in Atlanta. For ARC, per-mile tolls in this range are high enough to warrant considering managed lanes. Where major highway improvements were assumed in the study corridor, congestion was reduced so much that very low average toll costs of about 5 cents per mile were estimated. ARC does not consider managed lanes for average per mile tolls that low. Such logic checks can determine the methodology's sensitivity to tolls and level of congestion.

Pittsburgh, Pennsylvania

As part of a managed lane feasibility study in Pittsburgh, The Pennsylvania Department of Transportation (PennDOT) has developed a customized assignment process to estimate demand for a series of HOV and HOT Lane alternatives. The customized assignment process was structured to permit both fixed and variable tolls. The technique permits tolls to vary by time of day for individual peak and off-peak periods, as well as within a given time in response to demand. The technique, developed with TP+, utilizes a customized function embedded in the highway equilibrium assignment to dynamically determine toll values appropriate to maintain an acceptable level of service on the managed lanes. A logit-based route choice model, also embedded in the assignment routine, is then utilized to partition the trips between toll and non-toll paths within each iteration of the equilibrium assignment. This is an extension of a toll diversion model originally developed for Austin, Texas to support the financing studies conducted for the 2002 Central Texas Turnpike Project.

The original process was developed in order to support investment-grade financing analysis. The approach to the project was to utilize the existing trip generation, trip distribution, and mode choice components of the regional model. The model's 24-hour highway assignment procedure was replaced with the customized time-of-day assignment process with the embedded route choice model. The use of an embedded route choice model in the assignment process is to provide consistency between trips predicted to use the toll road and the trips assigned to the toll road, in an attempt to eliminate the need to "preload" toll trips and/or to use feedback procedures between mode choice and assignment to resolve any inconsistencies between predicted toll trips and assigned toll trips.

As part of the model development effort, data from Austin's stated-preference (SP) survey was extensively analyzed in order to determine appropriate coefficients for the route choice model (an SP survey was conducted as part of the Central Texas Turnpike Project due to absence of toll road facilities in Austin). This analysis was conducted for each of seven trip purposes, two auto occupancy levels (SOV, HOV) and truck trips. The stated preference analysis also explored travelers' biases regarding the method of payment, either as cash payments or electronic toll collection (ETC). From this analysis, separate route choice models were developed for each trip purpose and payment method. An interesting aspect of the stated preference analysis was the bias terms estimated for the use of the toll road and for the convenience of paying tolls electronically. As expected for each trip purpose, a bias equivalent to several minutes of time against the use of toll facilities was inferred from the analysis. However, in each purpose, a favorable bias for the option of paying tolls electronically effectively offset the negative toll bias. This suggests that tolls paid electronically may not have been viewed as a direct, out-of-pocket cost, but rather as another indirect, monthly cost, such as paying for fuel periodically during the month. This indicates that as the collection of tolls is "streamlined" via electronic toll collection methods, travelers effectively discount the inconvenience of tolls, making the decision to use a toll road a choice of route rather than mode.

The stated preference analysis did indicate that the probability of selecting a toll road for two trip purposes, home-based work (HBW) and work-based other (WBO), was sensitive to traveler's income, but did not identify variations related to auto occupancy. As a result of these findings and the implementation of the time-of-day assignment process, the TP+ assignment routine was modified so that the traveler's income would be available for the route choice model. This was accomplished by stratifying the HBW trip purpose into two separate directional flows (production-to-attraction and attraction-to-production) in each time period so that the average household income of the traveler's "home" zone was available for the route choice model. For the WBO trip purpose, the average income of workers employed in a given zone was estimated using the home-based work trips destined to that zone. The application of the process requires specific coding conventions that are applied to the highway network links. Each link is coded to represent permitted usage (SOV, HOV, trucks) and the presence of tolls. Toll values are provided for each vehicle type and the process provides a mechanism to alter toll rate to reflect discounts, if any, provided to ETC users. Additional codes are provided for toll facilities to reflect which vehicle types are assessed tolls and whether the tolls are held constant or vary with demand. With this coding system, it is possible to represent a wide range of tolling strategies simply by altering individual codes.

The process is fully contained within a conventional equilibrium assignment. Within each iteration of the assignment process, toll and non-toll paths are skimmed for each vehicle type. The logit-based route choice model then partitions the trips by trip purpose and vehicle type (SOV and HOV) based on the toll cost and times from the toll and non-toll paths along with the payment method (cash or ETC). The equilibrium assignment loads tolled and non-tolled trips from that iteration, then skims the network with the current assigned traffic, and repeats the process. The assignment iterations continue until equilibrium reaches a convergence. The final tolled and non-tolled traffic is calculated as the weighted average of the iterations, as determined by the equilibrium assignment technique. For scenarios where variable pricing is being analyzed, the assignment process provides a listing of the toll values and tolled traffic by vehicle type for each iteration, which permits the analyst to calculate the final weighted toll value predicted by the model.

The embedded toll adjustment function increases tolls at an accelerated rate as volume increases in order to maintain reasonable travel times. The function can either increase or lower tolls in response to the estimated traffic of each assignment iteration. The function also has the ability to accept upper and lower limits for the toll charges. The function was based on the volume / toll cost relationship utilized for I-15 in San Diego. Initial trials of the function provided reasonable results similar to the experience observed for I-15. In San Diego, the average toll rate paid on a recent typical a.m. peak was $3.06 for time-savings of approximately 4.5 minutes. For the Pittsburgh corridor, the average toll was estimated $3.57 for a little more than 5 minutes of time-savings.

The implementation of this modeling process inside of a regional model with a recursive feedback process is relatively straightforward since the technique is embedded directly in the highway assignment procedure. However, neither the Austin nor Pittsburgh models utilize feedback loops to pass the congested travel times and costs back to trip distribution. The implementation of feedback loops into the regional models would increase the internal consistency through the entire modeling process. Additional refinements and testing of this new procedure will be conducted as part of managed lane feasibility studies currently being conducted for San Antonio, Texas.

Washington, D.C.

The Metropolitan Washington Council of Governments (MWCOG) uses a post-processing methodology within the framework of its four-step model for developing managed lane forecasts. Currently under development, the methodology will be applied to evaluate a proposed HOT lane project in Northern Virginia.

Managed lanes and general-purpose lanes are explicitly coded in MWCOG's highway network. Highway pricing is addressed by converting tolls to equivalent travel time values for all pertinent i/j interchanges, which are in turn added to travel times developed by skimming the highway network. Highway accessibility is, therefore, reduced when tolls are imposed. Equivalent travel times are developed by traveler's income to accommodate MWCOG's income-stratified trip distribution model, and by vehicle type for use in the mode choice and traffic assignment models. Through the application of a diversion method, traffic from general-purpose lanes is reallocated to the managed lane in a magnitude equivalent to the excess capacity of the managed lane, while maintaining an acceptable level of service on the tolled facility.

To achieve this goal, an initial run of the four-step modeling process is applied to estimate the background HOV traffic on managed lanes. Next, an automated procedure is used to assess the amount of spare capacity available on each managed lane freeway segment. The ideal capacity for HOT lanes ranges from 1,400 to 1,800 vehicles per hour per lane. The spare capacity is, therefore, defined as the ideal capacity less the 'background' hourly HOV volume, as developed from the initial application of the regional travel demand model. Finally, traffic on the general-purpose lanes is diverted to the managed lane in the amount of calculated residual capacity on a section-by-section basis.

The traffic diversion procedure results in accessibility benefits to the vehicles diverted to the managed lane, as well as those remaining on the freeway main lanes. MWCOG is evaluating the merits of feeding back the restrained highway travel times, developed from the post-volume diversion process, through the trip distribution model.

San Diego, California

The San Diego Association of Governments (SANDAG) also uses a post-processor methodology to divert traffic from over capacity freeway lanes to adjacent managed lanes, as long as there is excess capacity and such as to maintain a level of service C on all HOV and managed lanes. When this criteria is violated, the traffic is diverted back onto the freeway general purpose lanes. Tolls paid by SOV drivers to gain access to HOT lanes are not considered in this procedure, although traffic assignment is performed based on generalized costs in which tolls are included. The procedure is maintained and applied in a GIS environment. Diversion is determined on the basis of the main lanes and the managed lane's V/C ratios. SANDAG's present structure of the mode choice model does not include a toll/non-toll nest.

Sacramento, California

In 1981, Kenneth Small and Harvey Rosen demonstrated that the results of a travel demand forecasting model can be used to calculate user benefits experienced from a given scenario. They derived the "consumer welfare measure" from a discrete mode choice model (5). The term is represented by the following formula for multinomial logit models:

$$W = \frac{1}{\lambda}\left\{\left[\ln\sum_{m} e^{V_m{}^f}\right] - \left[\ln\sum_{m} e^{V_m{}^o}\right]\right\}$$

Where:

λ is individual's marginal utility of income;

V_m^0 and V_m^f are the decision maker's utilities of all modes before and after policy implementation, respectively.

The user benefit term for nested logit models has a slightly different formulation:

$$W = \frac{1}{\lambda}\left\{\left[\ln \sum_m e^{\theta \ln \sum e^{V_m^f / \theta}}\right] - \left[\ln \sum_m e^{\theta \ln \sum e^{V_m^0 / \theta}}\right]\right\}$$

Where:

θ is the estimated nesting coefficient. All other definitions remain the same.

Small and Rosen also showed that λ can be obtained from the coefficient of the cost variable in discrete choice models. The user benefits term should be calculated for the various market segments that might exist in a travel demand model and be aggregated over all the set of market segments. The important benefit of this approach is that the user benefit term represents collective benefits of the transportation system under study, thus alleviating the need to estimate and add up various user benefits for each scenario.

Rodier and Johnston applied this method to a set of transportation system alternatives in the Sacramento area using Sacramento's four-step travel demand forecasting model (SACMET96), developed based on the region's household travel survey of 1991 (6,7). The consumer welfare term, described above, was modified to fit SACMET96's market segmentation of households by income and worker group. The model has a joint destination and mode choice logit model for work trips.

In order to model managed lanes more accurately, the HBW mode choice model was modified to include toll/non toll alternatives in its choice sets. Work trips in Sacramento's travel demand model see both travel times and costs in the trip distribution step, whereas, non-work trips are only sensitive to travel times. Home-based work trips see congested peak period travel times for trip distribution and the mode choice model. Traffic assignment uses only travel times as the measure of impedance. In SACMET96, only a fixed percentage of the shared ride vehicles can use the HOV lane.

The user benefit term was used for equity analysis, which showed that drivers in the higher income category are those who clearly benefit from the implementation of managed lanes. Tested scenarios were also compared with respect to travel-related measures (e.g., delay, VMT, trips), emissions, and economic benefits (e.g., travel time savings). The approach works well except for those instances where market segments do not include a cost term in their utilities. Under such circumstances, the consumer welfare term cannot be converted into a cost measure. The procedure is also documented and supported by FTA's Office of Planning for evaluating benefits of transportation scenarios (8).

Minneapolis-St. Paul, Minnesota

The Minnesota Department of Transportation (MNDOT) has conducted a pricing study using FHWA's Surface Transportation Efficiency Analysis Model (STEAM) (9, 10). STEAM is used in the evaluation of corridor and regional multimodal analyses, and addresses economic and environmental impacts of demand management projects.

Though applied as a post-processor outside of the framework of a regional model, STEAM is designed to accept input from a four-step travel demand model, as well as FHWA's Travel Demand Management (TDM) software. Through post processing of traffic assignment results, it refines the calculation of estimated roadway speeds under congestion. Developed based on principles of economic analysis, STEAM attempts to quantify environmental and economic impacts of various alternatives by presenting them in terms of monetary costs and benefits.

STEAM's environmental impact procedures include:

- Travel speed estimation
- Emissions analysis
- Fuel consumption
- Greenhouse gas emissions

Procedures used for economic impact analysis include:

- User benefits (i.e., travel time costs, vehicle operating costs, out-of-pocket costs such as transit fares and parking costs, accident costs, fuel taxes, and tolls).

- Revenues transferred from the user to the public agencies (tolls and fuel taxes).

STEAM provides default analysis parameters for up to seven transportation modes (auto, truck, carpool, local bus, express bus, light rail, and heavy rail). Users have the option to modify these parameters to suit their needs. The model can accommodate analysis by trip purpose and time of day and is comprised of the following four modules:

- User Interface – Includes default analysis parameters, as well as on-line help files.

- Network Analysis – Reads the traffic assignment output of a four-step travel model (e.g., link volumes, capacity, and length) and outputs zone-to-zone travel times and distances based on minimum time paths.

- Trip Table Analysis – Calculates user benefits and estimates of emissions, noise costs, accident costs, energy consumptions and other external costs.

- Evaluation Summary – Calculates benefit-cost ratios and present worth of the alternative under consideration.

Sketch Planning Approaches

Quick response analysis tools have also been used in the evaluation of value pricing projects. Decorla-Souza of FHWA has used Spreadsheet Model for Induced Travel Estimation (SMITE) in a value pricing case study of the Capital Beltway in Northern Virginia (11). The study evaluated the proposal of financing the expansion of the Capital Beltway by charging SOV tolls on the proposed new lanes.

Estimation of induced traffic (e.g., traffic resulting from faster travel speeds, diverted traffic from other routes, destinations, or modes) in SMITE is based on the elasticity of demand with respect to travel time. An equilibration of price and demand is also part of the procedure. A modified version of SMITE (referred to as SMITE-Managed Lane or **SMITE-ML**) with a pivot point mode choice model was used in the case study. The pivot point logit model estimated changes in travel demand on different modes of travel resulting in changes to travel time, tolls, and improved transit service. A variety of performance statistics are generated for each tested alternative and used in the evaluation task. The model is relatively simple to implement and can be considered a reasonable tool for the initial screening of alternatives or in situations where results of formal travel models are not readily available.

Another similar quick response analysis package, also developed by Patrick Decorla-Souza of FHWA, is the Sketch Planning for Road Use Charge Evaluation (**SPRUCE**) model (12). Using a pivot point mode choice technique, the model estimates changes in a traveler's choice of mode and the associated revenues, costs, and travel time delays. The model is designed to address both HOT lanes and Fast and Intertwined Regular (FAIR) lanes. The idea of FAIR lanes is a relatively new value pricing concept intended to overcome the equity issue normally associated with implementation of HOT lanes. Under a FAIR lane scenario, freeway lanes are separated into two sections: Fast and Regular lanes. Fast lanes are dynamically-priced (tolls are electronically charged) to ensure uncongested traffic movement under conditions close to free flow speeds. Users of Regular (non-tolled) lanes, on the other hand, would still be experiencing congestion but would be eligible to receive credits should their vehicle be equipped with electronic tags. The credits, set as a portion of the Fast lane toll price, are meant to compensate the Regular lane travelers for giving up the right to use the converted Fast lanes. Accumulated credits could be used toward the use of Fast lanes or transit and paratransit services.

Using the estimated daily freeway and arterial traffic volumes under the Base case scenario, estimates of vehicle demand and delays are prepared for the study corridor by hour of the day. Application of a pivot point mode choice model estimates the change in mode share for each alternative (based on anticipated changes in travel cost and time within the corridor) and the resulting estimates of vehicle demand and delays for each hour and each alternative. The underlying assumption of the technique is that through the application of variable pricing, the entire capacity of the managed lane is utilized and, therefore, no delays are foreseen for those vehicles on the managed lane. The model also considers the effects of spill-over demand on nearby arterials by calculating delays experienced on the corridor arterials resulting from the diversion of freeway traffic. Arterial network management and capacity enhancements are integral components of FAIR lanes value pricing scenarios.

The model calculates measures of consumer surplus for the new carpoolers and transit riders as well the single-occupant vehicles and previous carpoolers who continue to use freeway main lanes.

Conclusion

There are relatively few agencies that have effectively incorporated toll-based pricing scenarios as part of their travel demand modeling procedures. Current state of practice ranges from post processors and sketch planning exercises to the use of more sophisticated activity-based models. Existing value pricing modeling procedures may be grouped into the following categories:

- Modeled as part of an activity-based model, e.g., Portland, Oregon;

- Modeled within the mode choice component of a sequential travel demand model (e.g., Phoenix, Arizona and Sacramento, California);

- Modeled within the highway assignment module, (e.g., Pittsburgh, Pennsylvania and Atlanta, Georgia);

- Modeled as a post-processor either within the framework of a four-step regional model (e.g., Washington, D.C. and San Diego, California) or outside of the regional model using the output of a four-step travel demand model (e.g., STEAM used in Minneapolis-St. Paul).

- Modeled as a sketch planning methodology, e.g., SMITE-ML and SPRUCE

In general, the degree of sophistication in modeling value pricing scenarios is a direct function of the sophistication of the travel demand model in use. Table 1 provides a comparative summary of non-sketch planning methodologies documented in this report. The comparison is done with respect to the above categories of the applied methodologies highlighting key variables and features employed by each procedure. Recommendations for a "staged" approach to modeling toll-based value pricing policies by NCTCOG are presented below, ranging from long- to mid- to short-run alternatives. A decision regarding the selection of the most appropriate approach is highly dependant on the available resources (budget and time) and the level of desired model accuracy and sensitivity.

Activity-based models are perhaps the most appropriate tools used in addressing toll-based congestion pricing strategies. They provide the most behavioral framework for the implementation of travel demand models. With its higher level decision nests fully informed about lower level choices, a well-estimated and calibrated model can provide the best framework to analyze policy driven issues. Augmenting the revealed preference activity survey with stated-preference data in the model estimation phase ensures the sensitivity of the model to non-existent alternatives at the time of model development (to the extent of the reliability of stated-preference surveys). However, few such models are currently in operation. Portland Metro is the pioneer MPO in implementing such a model, and has used it successfully in a value pricing study as mentioned above. Even with an operational model on hand, model application for variable tolls policy analysis is resource-intensive and would require many application iterations. Undertaking the estimation and implementation of an activity-based model is a major effort, perhaps not in the short-range modeling horizon for NCTCOG. However, NCTCOG's current involvement in modeling efforts led by the University of Texas toward the development of an activity-based transportation/air quality model makes this a potential **long-run** modeling alternative for NCTCOG. The current state of travel demand modeling is slowly but surely heading towards the development and implementation of tour-based and activity-based models.

The next best alternative within a four-step modeling framework is the development of a mode choice model with toll and non-toll nests for work and non-work auto alternatives. The presence of tolls in the utility equations of auto users ensures robustness of results when assessing congestion pricing scenarios, since travelers' utilities are *directly* affected by the value of tolls and so are the respective mode shares. Travel time highway skims with and without tolls, and a travel time-savings variable are also included in the utilities of auto modes. In conjunction with this approach, a trip distribution model (be it a destination choice or a Gravity model, with a strong preference for the behavioral aspects of the former) that uses the LOGSUM term of the mode choice model as the measure of impedance will result in the model's sensitivity to toll costs, and accessibility in general. This is a theoretically sound way of approaching this issue. Again, enriching the model estimation database of revealed preference data with selected stated preference surveys can increase the model's sensitivity to policies regarding modes and alternatives for which no observed data is available at the time of model development. The current structure of NCTCOG's mode choice model may be easily expanded to include the toll/non-toll nests under the auto submode alternatives. Feeding back the mode choice model's LOGSUM term to the trip distribution model (even in its present Gravity model structure) would further enhance the performance of the model as the distribution of trips becomes sensitive to tolls as well. This approach may be considered as a **mid-run** strategy due to the need for model estimation, validation, and calibration. It can be implemented with relative ease and moderate budget and will further improve and 'complete' the existing structure of NCTCOG's model. It is important to emphasize the importance of the observed correlation between travelers' income and the likelihood of using toll roads. All else being equal, higher income travelers are more likely to use tolled lanes than those with lower incomes. It is, therefore, imperative to control for income in value pricing modeling. This can be achieved through the market segmentation of the mode choice model by income categories, or by reflecting variations in LOS and cost coefficients by travelers' household income.

For the **short-run**, a post mode choice highway assignment procedure, similar to what is currently used in Pittsburgh or Atlanta can be implemented within the exiting framework of NCTCOG's travel demand model. The iterative approach allows for the equilibration of tolls and demand while maintaining a desirable LOS on the managed lanes. The approach has the advantage of coexisting within the current structure of the model. Provision of a feed back loop between the highway assignment and trip distribution and mode choice components, upstream in the sequential model, would tie the process to the remaining components and provide more stable and refined results. Alternatively, a much simpler post-processing approach could be implemented using a diversion method, where post-assignment highway volumes in congested corridors are diverted onto the adjacent managed lanes based on the available excess capacity of the managed lane, while maintaining a minimum level of service. The approach is relatively simple to implement, and can easily be developed and applied within the NCTCOG's existing modeling framework with the least amount of effort. By the same token, such a simplistic and non-behavioral procedure lacks the flexibilities and sensitivities that the more advanced mode choice- or the assignment-based approach could offer. The degree of sophistication in modeling value pricing scenarios drives the analyst's ability to answer detailed policy related questions, such as determining the optimum level of toll that would encourage facility usage and prevent built-up of congestion at the same time.

TABLE 1 Comparative Summary of Modeling Methodologies

Modeling Methodology			Portland, OR	Phoenix, AZ	Atlanta, GA	Pittsburgh, PA	San Diego, CA	Sacramento, CA	Washington, DC
TOLL CATEGORIES:	Vehicle Type	(Car, Truck)	Y	Y	Y	Y			
	Occupancy Level	(SOV, HOV)	Y	Y	Y	Y			
	Time Period	(Peak, Off Peak)	Y	Y	Y	Y			
	Payment Method	(Cash, ETC)				Y			
TOLLS INFLUENCE:	Trip Distribution		Y	Y				Y	Y
	Mode Choice		Y	Y	Y	Y		Y	Y
DIVERSION MODELED:									
	Within Regional Model		Y	Y		Y		Y	Y
	Post Process - Model				Y				
	Post Process - Off Model						Y		
TOLL DIVERSION METHOD:	Mode Choice Model	Trip Purpose	Y	Y	Y			Y	
		Auto Occupancy	Y	Y	Y			Y	
		Payment Type							
		Feedback Loop	Y	Y				Y	
		HOV/Toll Trips Preloaded					Y		Y
	Highway Assignment *(Route Choice Submodel)*	Trip Purpose	Y			Y			
		Auto Occupancy	Y			Y			
		Vehicle Type	Y			Y			
		Payment Type				Y			
	Highway Assignment *(Equivalent Time Penalties)*	Trip Purpose							
		Auto Occupancy			Y		Y		Y
		Vehicle Type			Y			Y	
		Payment Type							
DIVERSION SENSITIVE TO:	Household Income		Y			Y		Y	
	Assignment Estimated Congestion		Y	Y	Y	Y	Y		Y
	Tolls Varied by Estimated Congestion		Y	Y	Y	Y			

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